Appendix B

Olivier Haeberlé
Assistant-Professor at Université de Haute-Alsace (since 1998)

Researcher at Laboratoire MIPS in the LabEl group

Groupe Lab.El - Laboratoire MIPS
Université de Haute-Alsace
IUT Mulhouse
68093 Mulhouse Cedex FRANCE
phone: + 33 (0)3 89 33 76 60
fax: + 33 (0)3 89 33 76 05
o.haeberle@uha.fr

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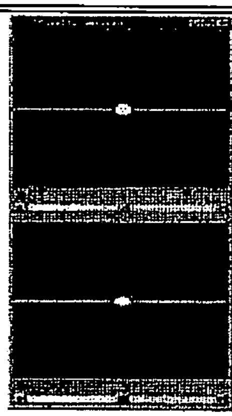
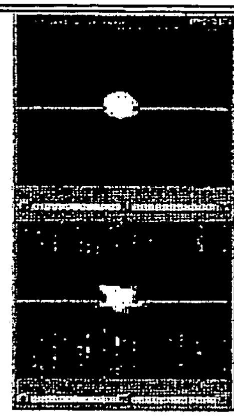
Research Fields:

Optical Systems and Image Processing 

I work on optical properties of **imaging systems**, more specifically on the **microscope** (with all variants). Several image formation models exist. One can then compute the Point Spread Function of the microscope, which characterizes its resolution (left picture). Every **modelisation** is based on a model and relies on the knowledge of some **parameters**, which may **differ** from their actual values, leading to important differences between computation and experiments:

	
Computed Point Spread Function (2-D xy and xz cuts)	**Recorded Point Spread Function (2-D xy and xz cuts)**

Some parameters of the model are easy to measure (thickness and index of the coverslip for exemple), but other are very difficult or even impossible to measure in pratice, as the depth of the specimen under the coverslip, the immersion oil index of refraction (which may vary with temperature), or the effective numerical aperture of the objective.

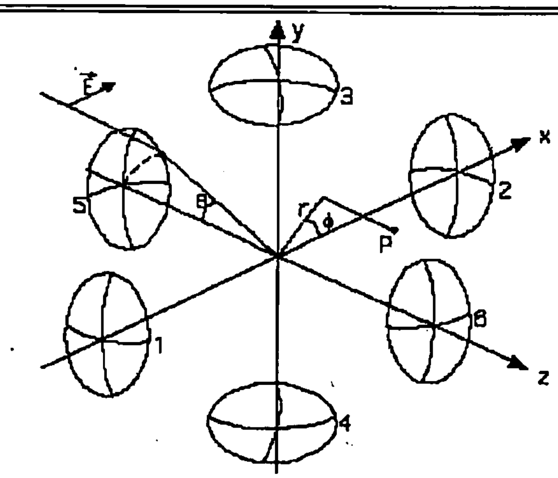
I have shown that it is possible to **recover these parameters** from a measure of the PSF [1] . This result is important for biologist using microscopes, helping them to precise the experimental protocol of image acquisition. Moreover, one can then use for deconvolution of the image a computed PSF which is noiseless and simultaneously as close as possible to the experimental PSF.

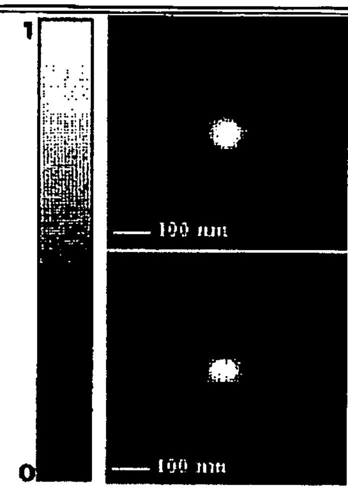
One can then use in better conditions the **deconvolution** algorithms, which are the second topic of the lab. The acquired images suffer from **blurring** and **noise**. Deconvolution can (partially) **restore** the images and **correct** these defects.

We work to **improve the algorithms** by the **automation** of the procedure and measurements [2][3].

My work has also lead me to propose a new concept of high resolution microscopy, called **Multiple Objective Microscopy (MOM)** [4]. Combining 4Pi and Theta microscopy, it is possible to achieve a very high resolution (100 nm laterally **and** axially) using low numeriacal aperture (0.8) objectives.
This result is important because:

- **from a theoretical point of view**, it shows that high resolution is not restricted to high numerical aperture objectives
- **in pratice**, it should be possible to study **large volumes** (of the order of 1mm^3) with a **very high resolution** because low NA objectives have long working distances.





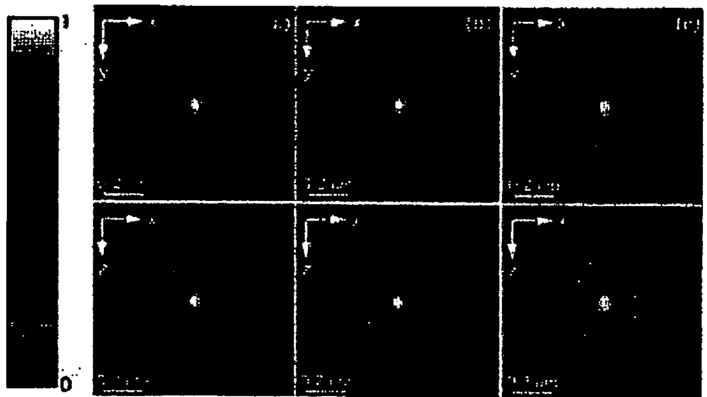
Concept of Multiple Objective Microscope (MOM)

objectives 1 to 4 are used to cohemtly excite the specimen
objectives 5 and 6 detect in 4Pi mode the fluorescence signal

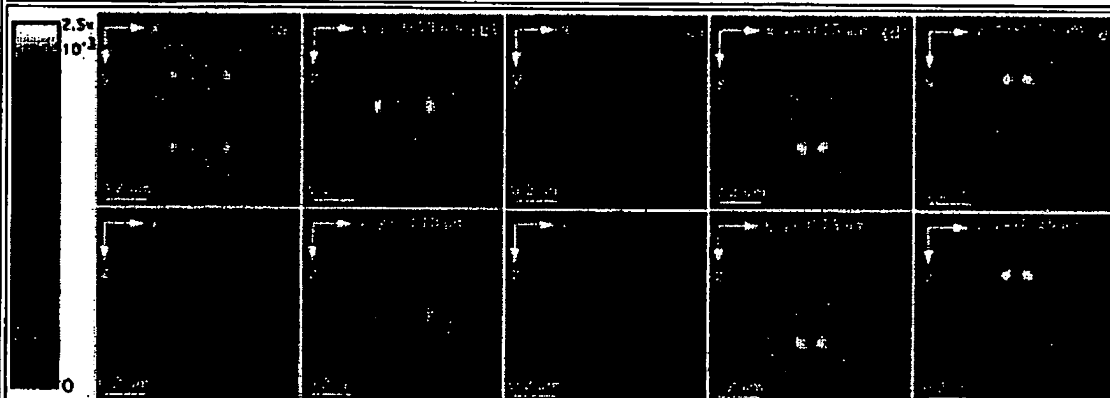
MOM PSF

top : lateral cut (xy) bottom : axial cut (xz)
Resolution is 108 nm in xy and 98 nm in z.
Excitation at 400 nm and detection at 450 nm

I also work on the confocal theta microscope , and proposed a new image formation model, which takes into account polarisation properties ot the fluorescence phenomenon. If fluorescent molecules are free to rotate, the PSF of a theta microscope (or a confocal microscope) is simply obtained by multiplying the excitation PSF by the detection PSF.
If fixed molecules are considered, one must take into account the polarisation moment induced by the excitation PSF, and the reemited dipole field is polarised. The shape and intensity of the PSF then strongly depends on the considered observed polarisation (parallel ort crossed polars) [6]:



Point Spread Functions for a theta microscope
using water immersion objectives with NA=0.8, excitation at l=400 nm and detection at l=450 nm (Cascade Blue – Molecular Probes). (a) conventional unpolarized isotropic radiation model. (b-c) dipole emission model. (b) x-polarized excitation, x-polarized detection. (c) z-polarized excitation, x-polarized detection.



Point Spread Functions
as for above figure, but for y-polarized detection. (a) x-polarized excitation, y-polarized detection. (b) same as (a)-bottom, but in the y=-0.18 mm and y=+0.18 mm plane respectively. Note the assymetry. (c) z-polarized excitation, y-polarized detection. (d-e) same as (c) but in the z=±0.15 mm and y=±0.15 mm plane. Note the complex shape of the PSF in that case.

New Photonic Sources 

I worked in this field during my Ph.D. and a post-doc at the Institute for Reference Materials and Measurements (IRMM) of the European Union in Geel-Belgium.

I worked (and still work a bit) on physical phenomenons which are candidate for **new photonic sources**. Specifically, **Transition Radiation** (Figure (a)), the **Smith-Purcell Effect** (Figure (b)) and **Grating Transition Radiation** (Figure (c)).

I introduced a new theoretical model, describing Smith-Purcell radiation emitted by an electron moving at an arbitrary angle with respect to the grating rulings (previous models were restricted to trajectories perpendicular to the rulings) [1][2].

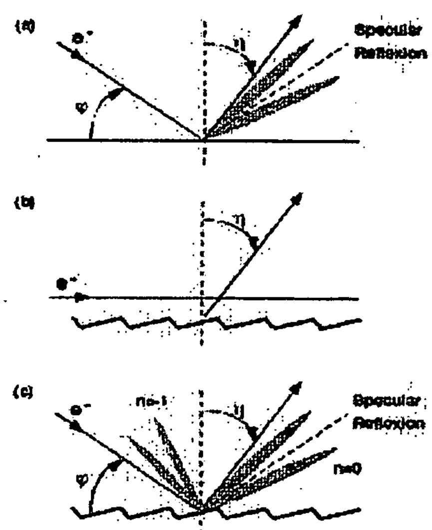
Simulations of sources with electrons in the 1 to 100 MeV range have been done, a domain for which no data existed. I have shown the interest of using low energies (E<10 MeV) interacting with millimetric gratings to produce **far-infrared radiation**. Smith-Purcell radiation is also a candidate to built Free Electron Lasers [3][6].

Experiments have been performed. **Two regimes** have been considered. When the electrons move **quasi-parallel** to the grating, the observed radiation has characteristics very similar to **Smith-Purcell radiation**. Spectra, polarization ans energy dependence have been measured between 20 and 120 MeV [4][7].

When the electrons hit the grating surface at **large incidence angles**, the emitted radiation has very different characteristics. The radiation has been compared with transition radiation from a flat surface, which has been intensively studied, from both the experimental and theoretical point of views.These experiments have characterized grating transition radiation.

A new theoretical model fro transition radiation has been developped, which is also valid for arbitrary surface profiles, contrary to previously existing models [5].

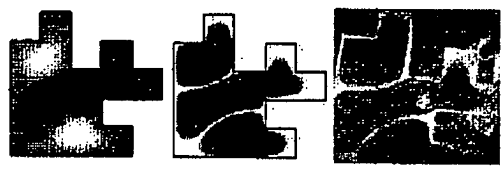
In collaboration with Chiba University, we studied Smith-Purcell radiation from photonic cristals. In particular, we have shown that photonic cristals permit to select very narrow and intense peaks of emission compared to diffraction gratings [6].



(a) Transition Radiation (b) Smith-Purcell effect and (c) Grating Transition Radiation

Download my PhD (PDF file, zipped) on Smith-Purcell radiation.

Physics of Fractal Systems



After my Ph.D., I studied the **physical properties of irregular systems** at Laboratoire de Physique de la Matière Condensée with Pr. B. Sapoval at the École Polytechnique (France). **Fractal geometry** gives a rigorous mathematical frame to study irregular objects.

This research has direct applications in solid state physics, optics and acoustics.

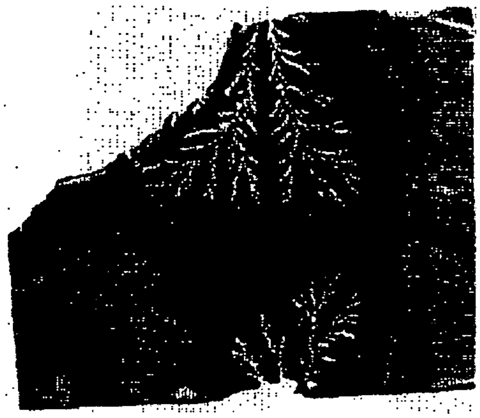
The **density of states** of irregular systems has been studied, showing an increase which follows approximately the **Weil law**.
The **wavefunctions** have also been studied. A **localisation** effect has been discovered, which has permit to give a first explanation to the anormal density of states observed in some demixed binary glasses [1].

We have also studied the losses in irregular resonators, whith application in **acoustics**, explaining the decrease of the quality factor which is observed for irregular systems compared to regular ones [2].

The high-frequency regime has been studied in the ray tracing approximation. The distributions of collisions obeys a Lévy law with an exponent a=-2. This could explain some properties of heterogen catalysis in the Knudsen diffusion regime [3].

An experiment to study the vibrational modes of **prefractal drums** has been carried out [4]. The three above pictures show a computed eigenmode, its simulated hologram and its recorded hologram

We have also discovered that **fractal arborescences** are produced when burning **copper foils** (with my collegue B. Keltz):



Large Prime Numbers

I joined a international team to prove two conjectures relative to prime numbers:

the Riesel conjecture and the Sierpinski conjecture 

I discovered some large prime numbers:

Prime	Number of digits	Discovery
220063.2^306335-1	92222	1999
485773*2^216487-1	65175	2001
485557*2^143570+1	43225	2001
470173*2^131982+1	39737	2001
222997*2^613153-1	184583	2001*
98939*2^575144-1	173141	2001*

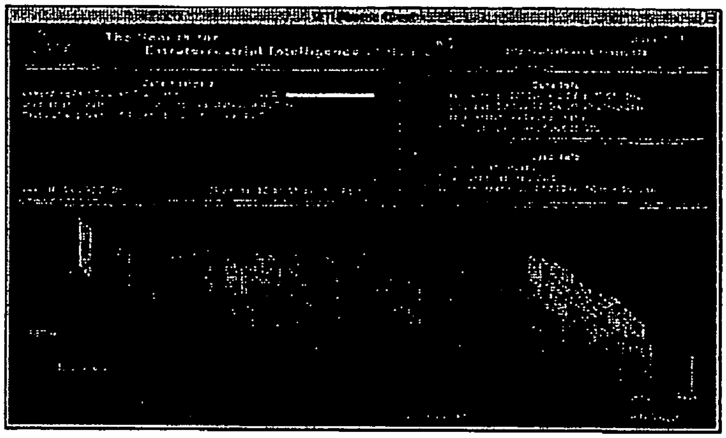
* I was lucky enough to discover these two Riesel prime numbers, which were the largests at their discovery dates

More informations at : www.prothsearch.net

SETI@UHA

I am member of the SETI@HOME program, to **analyse** data from **radiotelescopes**. Is there anybody out there?....

I founded the SETI@UHA group.... If you liked Jodie Foster in Contact.... join!



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